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APPLICATION

FOR

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TITLE: REDUCING THE BIAS ON SILICON LIGHT MODULATORS

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REDUCING THE BIAS ON SILICON LIGHT MODULATORS

Background

This invention relates generally to silicon light modulators.

A silicon light modulator or SLM uses an electric field to modulate the orientation of a liquid crystal (LC) material. By the selective modulation of the liquid crystal material, an electronic display may be produced.

The orientation of the LC material affects the intensity of light going through the LC material. Therefore, by sandwiching the LC material between a reflective electrode and a transparent top plate, the optical properties of the LC material may be modulated.

In particular, by changing the voltage applied across the electrodes, the intensity of the light being reflected by the reflective electrode may be modulated, thereby changing its gray level value. When light is shined on the cell, the reflected light can produce an image on a screen. By changing the voltage level on the electrodes, the image can be altered.

Generally, a silicon light modulator includes a transparent conducting layer that acts as the top plate and a pixel electrode that acts as the reflective electrode. As the voltage on the pixel electrode changes, the

reflected light intensity from the pixel area changes accordingly.

A transfer function, shown in Figure 5, describes the relationship between the voltage applied and the resulting light brightness. As the voltage increases, the pixel brightness or gray scale generally increases too. A number of gray scale levels may be represented, such as 256 levels, by dividing the available voltage up accordingly.

However, typical liquid crystal material needs a relatively high voltage for modulation. Generally the upper level of top plate voltage, V_b, is between 3.3 and 10 volts.

The supply voltage of modern silicon chips is moving downwardly from 2.5 volts towards 1.3 volts and potentially lower thereafter. Therefore, leading edge integrated circuit chips may not have the sufficient voltage levels to modulate typical liquid crystal materials. This may adversely affect the ability to integrate displays into silicon chips.

Thus there is a need for better ways to use available voltage levels, such as voltage levels associated with leading edge integrated circuit chips, for modulating liquid crystal displays.

Brief Description of the Drawings

Figure 1 is a schematic depiction of one embodiment of the present invention;

Figure 2 is a hypothetical graph of applied voltage versus time for a spatial light modulator;

Figure 3 is a graph of brightness versus bias voltage during a positive frame in accordance with one embodiment of the present invention;

Figure 4 is a graph of brightness versus bias voltage during a negative frame in accordance with one embodiment to the present invention; and

Figure 5 is a graph of brightness versus bias voltage in accordance with a prior art embodiment.

Detailed Description

Referring to Figure 1, a spatial light modulator 10 includes a liquid crystal layer 18. The liquid crystal layer 18 is sandwiched between a pixel electrode 20 and a transparent top plate 16. For example, the top plate 16 may be made of a transparent conducting layer such as indium tin oxide (ITO). Applying voltages across the liquid crystal layer 18 through the top plate 16 and pixel electrode 20 allows the reflectivity of the spatial light modulator 10 to be altered. A glass layer 14 may be applied over the top plate 16. In one embodiment, the top plate 16 may be fabricated directly onto the glass layer 14.

A drive circuit 23 applies bias potentials 12 and 22 to the top plate 16 and pixel electrode 20 respectively.

In one embodiment, a liquid crystal over silicon (LCOS) technology may be used.

Referring to Figure 2, the drive signal 12 is applied to the top plate 16 and the drive signal 22 is applied to the pixel electrode 20. During a positive frame, a signal 12 of $-V_a$ is applied to the top plate 16. During the negative frame, a voltage of V_b is applied to the top plate 16. At the same time, the pixel electrode voltage 22 is applied. The voltage 22 reaches a peak equal to the voltage level b during the negative frame. The difference between the voltage level b and the voltage V_b is indicated as the voltage a.

Thus, to provide a hypothetical example, if a liquid crystal material 18 has a 3.3 volt modulation voltage. The level b is equal to 1.8 volts. In the positive frame, the top plate 16 is biased to -1.5 volts (i.e., V_a = 1.5 volts). In the negative frame, the top plate 16 may be biased to 3.3 volts (i.e., V_b = 3.3 volts).

Referring to Figure 3, which shows the positive frame, the dynamic range is equal to b volts. If the spatial light modulator's supply voltage is a voltage equal to or higher than b volts, full modulation may be achieved by biasing the top plate to $-V_a$ volts in the positive frame. By using a negative voltage to bias the top plate 16, the entire dynamic voltage range (b volts) may be utilized while enabling lower overall supply voltages to be utilized

for modulation. Conventional designs may have negative frame voltage as high as the voltage a plus the voltage b.

Because the liquid crystal material 18 should not generally be biased only in the positive direction to avoid damage, the liquid crystal bias direction is altered on alternating frames. In the negative frame, the top plate 16 voltage may be V_b as shown in Figure 4. The spatial light modulator voltage still swings between zero and b volts. The corresponding gray scale is also reversed. As a result, zero volts produces the highest brightness and b volts produces the lowest brightness, as shown in Figure 4.

Thus, leading edge semiconductor supply voltages may be utilized to bias liquid crystal materials that would otherwise require supply voltages beyond those available with ever decreasing leading edge semiconductor supply voltages. As a result, an effective liquid crystal device may be achieved using existing and future silicon technologies. This may facilitate the integration of silicon and display technologies.

While the present invention has been described with respect to a limited number of embodiments, those skilled in the art will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of this present invention.

What is claimed is: